Test Simulations of the Kinetic Model for the Thermal Force based on the Monte Carlo Binary Collision Model

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For understanding of the impurity transport in the nuclear fusion plasmas, correct evaluation of the thermal force is very important. By Coulomb collisions with background plasma ions, the impurity receives the frictional force and the thermal force. The balance between those two forces determines the basic transport behavior of the impurity. In the fusion plasmas, there exist steep temperature gradients where the thermal force can overcome the frictional force. Then the impurity transport is dominated by the thermal force. This is why we need to evaluate correctly the thermal force on the impurity. The purpose of study is to develop a numerical model of the thermal force based on the Monte Carlo Binary Collision model [1] (abbreviated as BCM).

Originally the BCM was designed for the full kinetic plasma simulation such as the PIC simulation [2], where the velocity distribution of background plasma is self-consistently calculated. The full kinetic simulation is very useful to understand the basic physics of the impurity transport; however, it is too massive to apply such a full kinetic model to the realistic size simulations. Therefore, most of present impurity transport codes in realistic size simulations are coupled to the background plasma simulation code with the fluid model, which assumes that the background ion velocity distribution is close to an equilibrium Maxwellian. If we calculate, by the BCM, the collisional force on the impurity by sampling the background ion velocity form the Maxwell distribution, the frictional force is correctly evaluated, whereas the thermal force is not evaluated.

To solve this problem, by using the distorted Maxwell distribution with the temperature gradient ∇T_b in 13-moment expansion [3] for the background velocity distribution, we have developed a numerical model of the thermal force in the case without magnetic field [4].

In order to validate our new model, we need to perform test simulations in the wide range of the background plasma parameters. In the present study, we have done a series of systematic simulations for the parameters such as: i) impurity species (the mass m_a, the charge state Z_a), ii) background ion species (the mass m_b, the charge state Z_b, the density n_b, the temperature T_b, the magnitude and the direction of temperature gradient ∇T_b, the flow velocity $\mathbf{u}_b$). Based on the results of these simulations, the applicable limit of our new model will be discussed.

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